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SUMMARY

This is an interim progress report on a study to determine whether certain tracking tasks can be used as accurate indicators of stresses on human beings.

The task used for this work is Zero Input Tracking in which the only input is the subject's own error, hence the errors can give a direct indication of the condition of the subject. A specialized instrument, the Zero Input Tracking Analyzer, or ZITA was constructed for use in these tests.

Preliminary work showed that "auditory shadowing" even by a skilled subject could cause catastrophic degradation in performance of a tracking task.

The present report investigates the effect for an acceleration control tracking task over a wide range of control stiffnesses (8.3 to 915.0 mils/second^2) and control lag (0.0 to 1.255 seconds).

The results indicate, as a working hypothesis-:

(a) That the percentage increase in error due to control lag, and due to auditory shadowing is independent of control stiffness.

(b) That the effect of auditory shadowing is small (40%- 50% increase in error) with no lag, but very great (over 200% increase in error) if the lag is 0.3 seconds or more.

(c) That under conditions where severe degradation of the tracking task occurs, the accuracy of the auditory shadowing is also seriously degraded.

Since Garvey and Henson (U.S. Naval Research Laboratory Report 5204) showed that some secondary tasks produced very large degradation in performance with no lag, unaided control with lag in the presence of some more difficult auxiliary tasks may be impossible.

Further and more elaborate experiments on the effect are currently in progress.

THE EFFECT OF A PARTICULAR STRESS ON ONE MAN'S

PERFORMANCE OF VARIOUS TRACKING TASKS

BY

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(1)   INTRODUCTION

This experiment was performed to measure one man's performance in a tracking task under a "stress" condition.

This experiment forms one item of a series intended to

(a) Investigate the usefulness of tracking tasks as indicators of stress conditions.

(b) Establish the effect of a variety of stresses on operator performance, in the hope that a range of laboratory type stresses may be found which produce the same degradation in performance as occurs in combat. Hence, we may be able to simulate the effects of combat situations in the lab and thus investigate how actual tracking systems can be improved.

Preliminary results, Fig. 7, Table I, had indicated that the performance of some tracking tasks was greatly affected by "Auditory Shadowing" so this stress was used with a variety of tracking tasks covering a wide range of gains and lags. The Zero Input Tracking Analyser [1,2] (ZITA II) provided the tracking task and error readout which gave a measure of the stress.

(2)   EQUIPMENT

(2.1) The Tracking Task:

The tracking task is provided by ZITA. The subject sits in front of a display at a convenient distance and attempts to hold a spot of light in a fixed "zero" position by operating a control stick. The stick causes the spot to accelerate to the left or to the right and as only these two extreme positions of the stick are available

the best possible performance consists of a uniform oscillation of the spot about the zero. The displacement of the spot, (ε), in milliradians as seen by the subject, can be averaged over a time interval as the mean modular error ($\overline{|\varepsilon|}$), and can be obtained from the ZITA records. This is characteristic of the subject and his physical and mental condition and hence, may be a possible measure of his reaction to stress. (See typical record in Fig. 1)

The difficulty of the task can be varied by altering the "gain" of the display, that is, the angular acceleration of the line of sight to the spot following a control displacement ($\ddot{\lambda}$ max milliradians/sec/sec). Difficulty can also be increased by adding a time lag between the stick movement and the spot response.

(2.2)   The Stress:

This experiment was performed using one particular subject, Dr. Hamilton Mowbray of the Johns Hopkins University, Applied Physics Lab. and with "Auditory Shadowing"[3] as the stress condition. Dr. Mowbray was well accustomed to the Auditory Shadowing condition and had considerable experience in the use of ZITA.

Auditory Shadowing consists of repeating aloud lists of words heard through earphones from a tape recorder while doing the regular tracking task. (See Appendix II). The subject's performance is monitored by recording his output and comparing it with the original list. Care is taken to use words of similar difficulty in a random order and a sufficient number of lists (e.g. 50) must be used to make it difficult for the subject to improve his performance by memorizing the list. Auditory Shadowing can of course, be increased in difficulty by simply increasing the speed at which the words are played back from the tape recording. In our case a speed of two words per second was used, with mostly 4 syllable words.

When Auditory Shadowing is used as a stress the subject is required to repeat the words list at the same time as he tracks. Hence, the subject must divide his attention between the two tasks. Auditory Shadowing in conjunction with tracking can perhaps be described as a "distraction" type of stress.

(3)   EXPERIMENTAL METHOD

The normal ZITA procedure is to train a subject on Gain 5 (an acceleration response to stick movement - "stiffness" - of 91.2 milliradians/second/second when the operator is situated 20" from the display), and the next step involves increasing the gain successively to the maximum of Gain 11 (2,910 mils/sec^2), then returning to Gain 5 and successively decreasing the gain to 1 (8.6 mils/sec^2) finally returning to Gain 5. Hence, three readings

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are taken on Gain 5 which serve as a check to ensure that the general level of operator performance does not vary during the experiment.* Each gain setting is held for 1 minute during the run giving a total duration of 13 minutes. A typical set of results for Mr. Norman K. Walker, a highly skilled subject, is given in Fig. 3. The stress condition was added by turning on the tape recorder and requiring the subject to repeat the words lists aloud after each no-stress run at Gain 1,3,5,7, and 9, for a further minute, while tracking at these gain settings.

The tracking task is made more difficult by adding a first order lag so the subject's tracking ability was tested with three different lags in the tracking device, with and without stress. Lag 1 is 0.105 seconds, Lag 2 is 0.345 seconds and Lag 3 is 1.255 seconds.

(4)   PROCEDURE**

The subject wore earphones at all times, and was situated with eyes approximately 20" from the target - a comfortable distance. The runs started at 10:42 A.M., and ended at 4:32 P.M., with breaks for coffee and for lunch. To give a small rest period, the ZITA II equipment was stopped for a few seconds after each Gain setting but it is doubtful whether this is a good technique since this implies that in each case the operator settle down to the tracking task inside the first 2 seconds after the error integration begins. Some runs therefore started with an initial large error, and we attempted to allow for this by ignoring any initial step in the record of integrated error.

The experiment consisted of five runs of about one half hour each; two runs with no lag, and one run each with the lags described above.

(5)   RESULTS

(5.1)   General Tracking Accuracy:

All tracking results are listed in Tables II and through VI and are finally expressed in terms of the mean error ($|\bar{E}|$) mils, for various values of stiffness, $\overset{..}{\Delta}$ max (mils/sec^2).

The subject's results for the no stress case can be compared with those for Walker taken from other work. Walker's result for no

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*   this procedure does not follow the standard "counter balanced" design usually employed in psychological experiments. A discussion of this point is given in Appendix I.

** See Appendix II.

lag is given in Fig. 2 and Table VII and may be used as a standard
to roughly eliminate the effect of gain variations. Mowbray's re-
sults are plotted in Figs. 3,4,5 & 6 and are compared with Walker's
no lag result.

When Dr. Mowbray last used the ZTTA equipment in Dec. 1962 (Fig 7,
Table I), he was trained for 10 - 15 mins. to a roughly asymptotic
performance but appreciably worse than Walker. The first full run of
the day, (no lag) Table Ia, after a single two-minute practice run,
snowed that his error was now some 30% greater than the standard
set in Fig. 1.

The results of Mowbray's second trial with no lag, Fig. 3 and
Table III, showed only 15% greater error than Walker. His per-
formance was greatly improved but results at low gains were
scattered. This scatter at low gains may be due to the difficulty
the operator encounters of deciding which point on the display
should be treated as the zero at the very small errors (or also
possibly due to eyestrain). Hence, in a second analysis of the
data, we took the liberty of ignoring the results for Gains 1,2,3,
& 4. Table VII shows that the omission of the low gain tests
improves the performance relative to Walker, and the consistency
of the results, but has no effect on the increase of error due
to stress.

After lunch tests were made with the various lags. In general,
the results are as expected and show that the increase in error
(above the standard of Fig. 2) due to lag, is not dependent on
gain and increases with the lag.

The unusually high error for Lag 1 as compared to Lag 0 and Lag 2
is attributed to the fact that insufficient time was allowed after
a hurried lunch to recover full alertness which was achieved on
the interposed lag runs. (We noted at the time that the subject
said the task felt "easier" with the words list; a comment ob-
viously negated by the measured results, but possibly implying a
feeling of greater alertness.) It is possible that a more elab-
orate counterbalanced experimental design with several separate
test runs at each lag spread out through the day would have min-
imized this effect, at the expense of increased scatter when
varying the gain.

(5.2) Effect of Stress

Results with stress are also given in Tables II through VI and
Figs. 3,4,5, & 6.

The Auditory Shadowing caused an increase in error at all values
of lag, although the subject himself stated that he felt his task
was easier for Lag 0 and 1 with the shadowing. The percentage
increase in error due to shadowing at a particular lag was once

more independent of gain - Table VIII, and varied from 50% at no lag to 200% with 1.255 seconds lag.*

Auditory Shadowing probably produces a fairly mild stress. The effect due to stress on a no-lag second order system measured by Garvey and Henson[6] ranges from 20% for the "secondary arithmetical task" to 200% for a "secondary visual task."

It is likely the secondary arithmetical task is comparable with Auditory Shadowing in its effect on the subject, and the results are also comparable.

Nevertheless, this simple stress produced an extremely large increase in error for the systems with 1.255 seconds lag, indicating that with a more difficult stress task such as the "secondary visual task" the loss in tracking accuracy might well be catastrophic.

(5.3) Auditory Shadowing Performance

The tape recordings were analyzed by Dr. Mowbray's assistants using very strick criteria. In addition to the obvious errors such as the complete omission of a word, any slurring or mispronunciation was counted as a mistake. On the other hand, delay in response was not penalized, since part of the subject's learning technique is to determine the optimum time for "storage" of the words as they are read out.

Results are given in detail in Table IX through XIII, and the averaged results are collected in Table XIV. These show clearly that the efficiency of shadowing degrades as the difficulty of the tracking task increases, as shown by the increase of tracking error. The number of errors range from 2 per word list with no tracking to 12 per word list when coupled with tracking at Lag 3.

Detailed examination suggests also that even during one run the words list errors are most likely to occur at the time when the operator is having greatest difficulty with the tracking task.

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* An anomalous result was found in Lag 3, when an increase in Gain from Gain 5 to Gain 7 produced no increase in error. However, it was noticed that at Gain 5 the error spot almost reached the edges of the paper, and also at Gain 7. A subsidiary experiment[7] has shown that the results produced by ZITA are consistent except when the amplitude of the error display with long lags is great enough to approach the limits of the recording chart. In such case additional visual cues are provided to the operator, and up to two steps increase in gain produced no increase in error. With a further increase in gain, control is lost. Hence, the results for Gains 5, & 7, Table VI should be ignored.

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(1) The error results for the subject with no lag are comparable with the "standard" result for Walker, (Fig. 2) and are in agreement with earlier results for this subject.

(2) The effect of lag can be represented by a single factor for all gains, depending only on the lag.

(3) The effect of stress can be represented by a single factor for all gains, but varying with the lag.

(4) Results can be affected by variations of conditions during the day and some counterbalancing or other changes of the design are needed to reduce the effects.

(5) Auditory Shadowing would appear to be a fairly mild stress by comparison with those used by Garvey and Henson. Nevertheless, the increase in error due to the stress condition for control systems with a large lag is very great.

(6) The results appear to confirm the suggestion[8] that a man has a limited data-handling and decision-making capacity. A simple tracking task (no lag) together with a fairly difficult task - auditory shadowing - did not overload the system, and hence the results of the tracking on the shadowing and of the shadowing on the tracking are fairly small. However if the tracking task is of itself very difficult, then the addition of auditory shadowing overloads the human system, and both performances suffer severe degradation.

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The design of experiments using the ZITA equipment

Present day psychological experimental technique stresses the importance of "balanced" experimental design. This implies that if a series of subjects are to be tested under a number of different conditions then the conditions and tests will follow each other in a carefully selected sequence to ensure that the effect of "learning" of external conditions is controlled for over the group.

The technique has been very successful in reducing the variability of experimental results and is standard practice for most tests.

It is, however, cumbersome and time-consuming and one of the hopes in the design of the ZITA equipment that the requirement for balancing might be reduced or eliminated.

Most tracking experiments have used partially trained or untrained "naive" subjects. It is known that the performance of such subjects can improve by a factor of 3 or more during the course of an experiment, so the requirement for "balance" with such subjects is obvious. However, the use of "Rubric" tracking for 20 minutes or so with ZITA leads quickly to a "plateau" level of performance such that further improvement is very slow (Fig. 2 shows how well two sets of experiments on a given subject can link up). Provided that the change in tracking performance during the course of an experiment is small compared to the expected change due to the experiment it would seem that the requirement for "balance" to correct for "learning" would then be eliminated.

The effect of a change in "gain" or "stiffness" is now well understood, and would seem to be largely unaffected by outside conditions. Hence we may either eliminate gain as a variable, picking one preferred value for all experiments, or use gain as a stimulant to arouse and maintain a subject's interest. It is known, however, that in tracking a subject's performance is certainly affected by the previous run. In Fig. 2 a subject starts off at Gain 5 with a certain error. As the gain increases he reacts more quickly, and on recheck at Gain 5 his performance has improved. Similarly when the gain was decreased, his performance became worse. Hence a "balanced" design in which a high gain condition was followed by a low gain condition, or vice versa, or a high error condition, by a low error condition - would lead to increased scatter and possibly misleading results.

For this reason we prefer, at least as far as gain is concerned, to run through a series of gains for each condition as a batch.

However, "balance" is needed, we now believe, to eliminate long term effect over experiments such as those conducted recently by Lt. Col. Williams, and also extraneous effects such as the excessively high errors with Lag No. 1.

This can be achieved by splitting the gain sequence so that Gain 5 is always used, but in one series in combination with the odd gain values and in another sequence with even values.

A further factor to bear in mind is operator "motivation." It is found that if an operator is achieving his standard performance with no lag, and lag is switched in, his performance will immediately deteriorate. However, if he is tracking with Lag No. 1, a small lag, and the lag is suddenly removed without his knowledge, he will continue to track with little if any improvement in performance.

Apparently the task seems easier, but the subject ascribes this to practice or to some other excuse for not working harder. Putting it another way, to follow difficult task "B" with an easy task "A", will give misleading results. But if "A" is already at limit performance, a subsequent test on task "B" will be meaningful. Hence unless some way can be found to force the subject to his asympototic performance without his knowledge, he must not be left in ignorance of the tests but must be told the experimental conditions and perhaps even assigned a target performance.

CONDUCT OF AUDITORY SHADOWING TRIALS - extracted from G.H. Mowbray's
"Human Perceptual Limits," APL
Tech. Digest, Jan. Feb. 1962.

The subjects were required to listen through earphones to a 50-word list
of English words that had been recorded at a controlled rate of about
two words per second. The words, drawn from the Thorndike-Lorge lists
of the most commonly used words in the English language, were mostly two,
three, or four syllables long. As they were read, the subjects were re-
quired to "shadow" them, i.e., repeat them aloud as they were presented.

The subjects were all well-practiced in auditory shadowing before any
experimental trials were begun. The time required to attain proficiency
in this task varied from 2 to 4 hours, depending on the subject. The
experimenter decided on the basis of a subject's performance whether or
not he was ready to begin the experimental trials.

The duration of the words ranged from 200 - 573 milliseconds with a median
of 342 milliseconds. Hence with the average repetition rate of 2 words/
second, about 2/3 of the time is actually taken up by the words. It was
found that this forces the subject to store several words at a time be-
fore he can make his responses.

A typical list of 54 words is as follows -

Time	Word	Time	Word	Time	Word
2.7	happy	2.0	scenery	3.7	describe
2.6	whatever	3.2	balance	2.4	ultimate
2.9	return	2.5	texture	1.7	began
2.9	insist	2.6	number	2.5	muster
3.7	display	2.0	numerous	3.2	exchange
2.7	journey	2.1	electric	3.4	protest
2.1	possibility	3.1	chemical	2.3	pocket
1.5	target	2.4	soluble	2.2	fortress
2.0	purchase	3.4	magnify	2.4	farmer
3.7	resignation	3.0	specialize	2.6	contact
2.2	refuse	3.3	electron	1.8	license
1.5	describe	3.0	criticize	1.9	classic
2.2	affection	3.2	refugee	2.3	barracks
3.0	problem	1.7	thesis	2.4	knowledge
2.9	passenger	2.3	visitor	4.3	engineer
2.4	summer	2.2	complex	1.9	forget
2.6	falcon	3.6	musical	2.9	jealousy
4.0	complicate	2.4	blister	3.8	longitude

TABLE I

SUMMARIZED RESULTS FROM PREVIOUS EXPERIMENT

WITH DR. MOWBRAY AS SUBJECT. (DEC. 1962)

LAG	GAIN	$\ddot{\Delta}$ Max Mils/Sec^2.	$\mid \overline{\varepsilon} \mid$ Mils	$\dfrac{\overline{\mid \varepsilon \mid}}{\mid \overline{\varepsilon} \mid}$ Standard	Stress No Stress
0	5	95	2.65	2.3	1.21
	5WL	95	3.2	2.8	
1.0 Secs	5	95	10.4	9.0	3.27
	5WL	95	34.0	29.6	

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TABLE II

VARIATION OF TRACKING ACCURACY WITH GAIN - NO LAG

GAIN	STIFFNESS $\overset{..}{\Delta}$ Max (mils/sec^2)	READOUT (Spaces)	MEAN ERROR $(\bar{\varepsilon})$ (mils)	$(\bar{\varepsilon})/(\widetilde{\varepsilon})$ standard
time 10:42 A.M.				
5	91.2	2.4	1.31	1.14
5wl	91.2	3.7	2.02	1.76
6	168	2.05	1.82	1.03
7	282	2.20	3.36	1.16
7wl	282	2.40	3.68	1.27
8	542	2.20	6.30	1.24
9	915	1.60	7.60	.97
9wl	915	2.00	9.50	1.22
10 Fail	---			
11 Fail	---			
5wl	91.2	3.4	1.87	1.63
4	45.8	3.8	1.12	1.62
3	24.5	4.3	0.785	1.57
3wl	24.5	5.75	1.03	2.06
2	12.7	5.0 - 6.3	0.59 - 1.47	1.47
1	8.3	5.8	0.595	1.61
1wl	8.3	11.1	1.13	3.05
5	91.2	1.5	.82	.71
5wl	91.2	3.7	2.02	1.76

time 11:25 A.M. - Break for coffee and analysis of data.

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TABLE III

VARIATION OF TRACKING ACCURACY WITH GAIN - NO LAG   PHASE 2

GAIN	STIFFNESS $\ddot{\Delta}\, max$ (mils/sec^2)	READOUT (Spaces)	MEAN ERROR $(\bar{\mathcal{E}})$ (mils)	$(\bar{\mathcal{E}}) \big/ (\tilde{\mathcal{E}})$ standard
time 11:59 A.M.				
5	91.2	1.6	.875	.76
5wl	91.2	3.9	2.13	1.85wl
4	45.8	2.4	.699	1.01
3	24.5	3.0	.548	1.09
3wl	24.5	8.5	1.55	3.1 wl
2	12.7	6.4	0.75	1.87
1	8.3	10.5	1.08	2.90
1wl	8.3	10.65	1.09	2.94wl
5	91.2	1.5	.820	.71
5wl	91.2	2.4	1.31	1.14wl
6	158	1.9	1.68	.95
7	282	1.7	2.62	.90
7wl	282	2.0	3.06	1.06wl
8	542	1.75	5.00	.98
9	915	1.25	5.90	.76
9wl	915	1.85	8.78	1.12wl
5	91.2	2.4	1.31	1.14
5wl	91.2	2.55	1.39	1.20wl
time 12:27 P.M. - Break for lunch				

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TABLE IV

VARIATION OF TRACKING ACCURACY WITH GAIN - LAG 1

CAIN	STIFFNESS $\ddot{\Delta}$ Max (mils/sec^2)	READOUT (Spaces)	MEAN ERROR $(\bar{\epsilon})$ (mils)	$(\bar{\epsilon}) / (\hat{\epsilon})$ standard
time 1:30 P.M.				
5	91.2	6.00	3.28	2.85
5	91.2	5.60	3.06	2.04
5	91.2	6.80	3.71	3.24
5	91.2	4.50	2.46	2.15
5w1	91.2	9.85	5.40	4.70w1
6	158	5.40	4.77	2.70
7	282	4.95	7.62	2.64
7w1	282	9.20	14.10	4.85w1
8	542	5.2	14.9	2.91
9	915	4.0	19.0	2.42
9w1	915	6.25	29.7	3.80w1
5	91.2	4.4	2.40	2.08
5w1	91.2	8.2	4.48	3.89w1
4	45.8	5.6	1.65	2.40
3	24.5	6.4	1.17	2.34
3w1	24.5	8.8	1.61	3.22w1
2	12.7	8.2	0.96	2.40
1	8.3	8.0	0.82	2.20
1w1	8.3	12.8	1.31	3.54w1
5	91.2	5.4	2.95	2.56
5w1	91.2	7.05	3.86	3.36w1
time: 2:01 P.M. - Break for analysis of results				

TABLE V

VARIATION OF TRACKING ACCURACY WITH GAIN   LAG 2

GAIN	STIFFNESS $\ddot{\Delta}$ Max (mils/sec^2)	READOUT (Spaces)	MEAN ERROR $(\bar{\epsilon})$ (mils)	$(\dot{\epsilon})/(\epsilon)$standard
time:	2:25 P.M.			
5	91.2	3.10	4.25	3.70
5wl	91.2	4.8	6.60	4.40wl
6	158	1.7	3.80	2.14
7	282	1.3	5.00	1.72
7wl	282	4.8	18.5	6.40wl
8	542	1.8	12.8	2.50
9	915	1.7	20.2	2.60
9wl	915	4.2	50.0	6.40wl
5	91.2	2.4	3.30	2.86
5wl	91.2	5.5	7.55	6.57wl
4	45.8	2.3	1.70	2.45
3	24.5	2.2	1.01	2.02
3wl	24.5	8.2	3.75	7.50wl
2	12.7	4.7	1.39	3.47
1	8.3	6.0	1.54	4.16
1wl	8.3	8.8	2.25	6.00wl
5	91.2	2.0	2.28	1.98
5wl	91.2	5.0	6.88	5.95wl
time:	2:53 P.M.			

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TABLE VI

VARIATION OF TRACKING ACCURACY WITH GAIN   LAG 3

GAIN	STIFFNESS $\ddot{A}$ Max (mils/sec^2)	READOUT (Spaces)	MEAN ERROR ($\bar{\varepsilon}$) (mils)	$(\bar{\varepsilon})/(\bar{\varepsilon})$ standard
time 3:07 P.M.				
5	91.2	4.6	6.3	5.50
5	91.2	5.7	7.89	6.82
5w1	91.2	22.0	30.2	26.20w1
6	158	8.7	19.3	10.90
7	282	3.0	11.60	4.00
7w1	282	7.9	30.5	10.50w1
7w1	282	4.9	18.8	6.50w1
5	91.2	5.7	7.89	6.82
5w1	91.2	14.7	20.00	17.40w1
4	45.8	7.6	5.60	8.10
3	24.5	4.7	2.15	4.30
3w1	24.5	28.5	13.06	26.10w1
2	12.7	22.0	6.55	16.40
1w1	8.3	18.0	4.60	12.40w1
5	91.2	8.6	11.8c	10.30
5w1	91.2	14.4	19.70	17.10w1
time 3:34 P.M.				

TABLE VII

"STANDARD" VARIATION OF ERROR WITH STIFFNESS - (Feb. 1963)

(FROM COLLECTED RESULTS FOR N.K. WALKER - NO LAG)

Gain	Stiffness	$|\overline{E}|$
1	8.3	0.37
2	12.7	0.40
3	24.5	0.50
4	45.8	0.69
5	91.2	1.15
6	158.0	1.77
7	282.0	2.90
8	542.0	5.10
9	915.0	7.80

TABLE VIII

SUMMARIZED RESULTS

LAG	NO STRESS	WITH STRESS	STRESS NO STRESS
Zero (1st Run)	1.31 ∤ 0.22*	1.82 ∤ 0.56	1.39
(2nd Run)	1.15 ∤ 0.40	1.77 ∤ 0.83	1.54
0.105 secs.	2.50 ∤** 0.20	3.91 ∤ 0.59	1.57
0.345 secs.	2.69 ∤ 0.54	6.17 ∤ 0.86	2.29
1.255 secs.	8.12 ∤ 3.03	19.84 ∤ 7.6 ***	2.45
Zero (1st Run)∤	1.04 ∤ 0.20	1.53 ∤ 0.33	1.47
(2nd Run)	0.87 ∤ 0.12	1.27 ∤ 0.42	1.46

   * 95% Confidence Interval
  ** This result considered doubtful - Errors are much greater than in
     previous work
*** Excluding Gains Above 5 Because of "Finite Display" Effect.

  ∤ Excluding Gains Below 5 Because of Eye Strain, etc.

TABLE IX

ANALYSIS OF AUDITORY SHADOWING PERFORMANCE

NO LAG (TRACKING RESULTS IN TABLE II)

WORD LIST	CODE	GAIN	NUMBER OF MISTAKES	$[\bar{\epsilon}]/[\bar{\epsilon}]$ standard
15	24		?*	1.76
16	5	5	2	
17	10		1	1.27
18	5	7	1	
19	6		2	1.22
20	12	9	3	
21	27		6	1.63
22	29	5	1	
23	20		1	2.06
24	24	3	4	
25	18		5	3.05
26	7	1	4	
28	13		1	1.76
29	30	5	4	

Mean number of errors/word list = 2.7
Mean Tracking error ratio   = 1.82 $\pm$ 0.56

* results omitted etc.

TABLE X

ANALYSIS OF AUDITORY SHADOWING PERFORMANCE

NO LAG (PHASE 2)

(TRACKING RESULTS IN TABLE III)

WORD LIST	CODE	GAIN	NUMBER OF MISTAKES	$|\overline{E}|/|\overline{E}|$ standard
30	4 ⎤		1	
31	17 ⎦	5	1	1.85
32	1		1	
33	14	3	2	3.10
34	3		2	
35	26	1	5	2.94
36	15		5	
37	13	5	1	1.14
38	22		3	
39	22	7	4	1.06
40	25		8	
41	1	9	3	1.12
42	23		7	
43	8	5	3	1.20

Mean number of errors/word list = 3.0
Mean Tracking error ratio = 1.77 ⧸ 0.83

TABLE XI

ANALYSIS OF AUDITORY SHADOWING PERFORMANCE

LAG I

(TRACKING RESULTS IN TABLE IV)

WORD LIST	CODE	GAIN	NUMBER OF MISTAKES	$|\varepsilon|/|\bar{\varepsilon}|$ standard
44	15	5	6	
45	2		7	4.70
46	11	7	5	
47	7		11	4.85
48	11	9	4	
49	16		7	3.80
50	23	5	0	
51	16		15	3.89
52	9	3	3	
53	14		3	3.22
54	18	1	4	
55	6		6	3.54
56	2	5	0	
57	9		0	3.36

Mean number of errors/word list = 5.1
Mean Tracking error ratio = 3.91 $\pm$ 0.59

TABLE XII

ANALYSIS OF AUDITORY SHADOWING PERFORMANCE

LAG II

(TRACKING RESULTS IN TABLE V)

WORD LIST	CODE	GAIN	NUMBER OF MISTAKES	$(\bar{E})/(\bar{\epsilon})$ standard
1	12		6	
2	29	5	0	4.40
3	26		1	
4	24	7	7	6.40
5	3		3	
6	27	9	26	6.40
7	19		4	
8	25	5	5	6.57
9	20		4	
10	21	3	7	7.50
11	30		8	
12	8	1	10	6.00
13	17		0	
14	10	5	5	5.95

Mean number of errors/word list = 6.9
Mean Tracking error ratio = 6.17 $\measuredangle$ 0.86

TABLE XIII

ANALYSIS OF AUDITORY SHADOWING PERFORMANCE

LAG III

(TRACKING RESULTS IN TABLE VI)

WORD LIST	CODE	GAIN	NUMBER OF MISTAKES	$(\bar{\varepsilon})/(\bar{\varepsilon})$ standard
15	24	5	3	26.20
16	5		19	
17	10	7	0	10.50
18	5		49	6.50
19	6		22	
20	12	5	7	17.40
21	27		?	
22	29	3	5	26.10
23	20		8	
24	24	1	7	12.40
25	18		8	
27	28	5	16	17.10
28	13		11	

Mean number of errors/word list = 12.1
Mean Tracking error ratio   = 19.84 $\pm$ 7.6

TABLE XIV

COLLECTED RESULTS FOR AUDITORY SHADOWING

Tracking Task	Verbal Errors/Words List	Tracking Errors $(\bar{E}/|\bar{E}|$standard
none	2.0*	
acceleration - no lag	2.7	1.82 ∤ 0.56
" repeat	3.0	1.77 ∤ 0.83
" Lag No. 1	5.1	3.91 ∤ 0.59
" Lag No. 2	6.9	6.17 ∤ 0.86
" Lag No. 3	12.1	19.84 ∤ 7.6

* Mean value from other work.

DRIFT CHECK

ERROR READOUT

57.3 SECONDS

θ

SUBJECT — WALKER
GAIN — 5
LAG — 2 (0.31 SECS)
DISTANCE — 20"

MAR 19TH, 1963

STICK
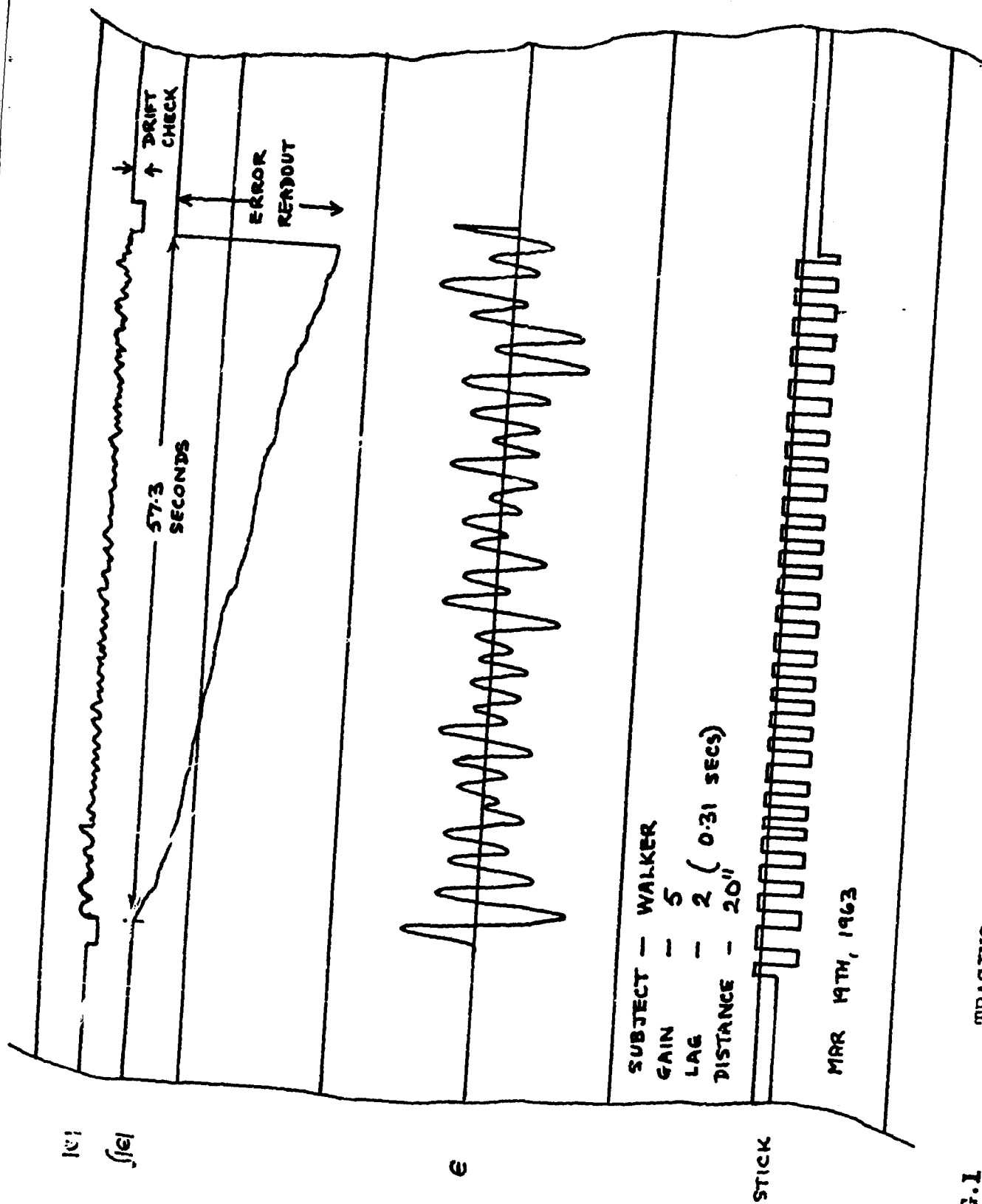
FIG.1   TRACING   OF   TYPICAL   ZITA   II   RECORD
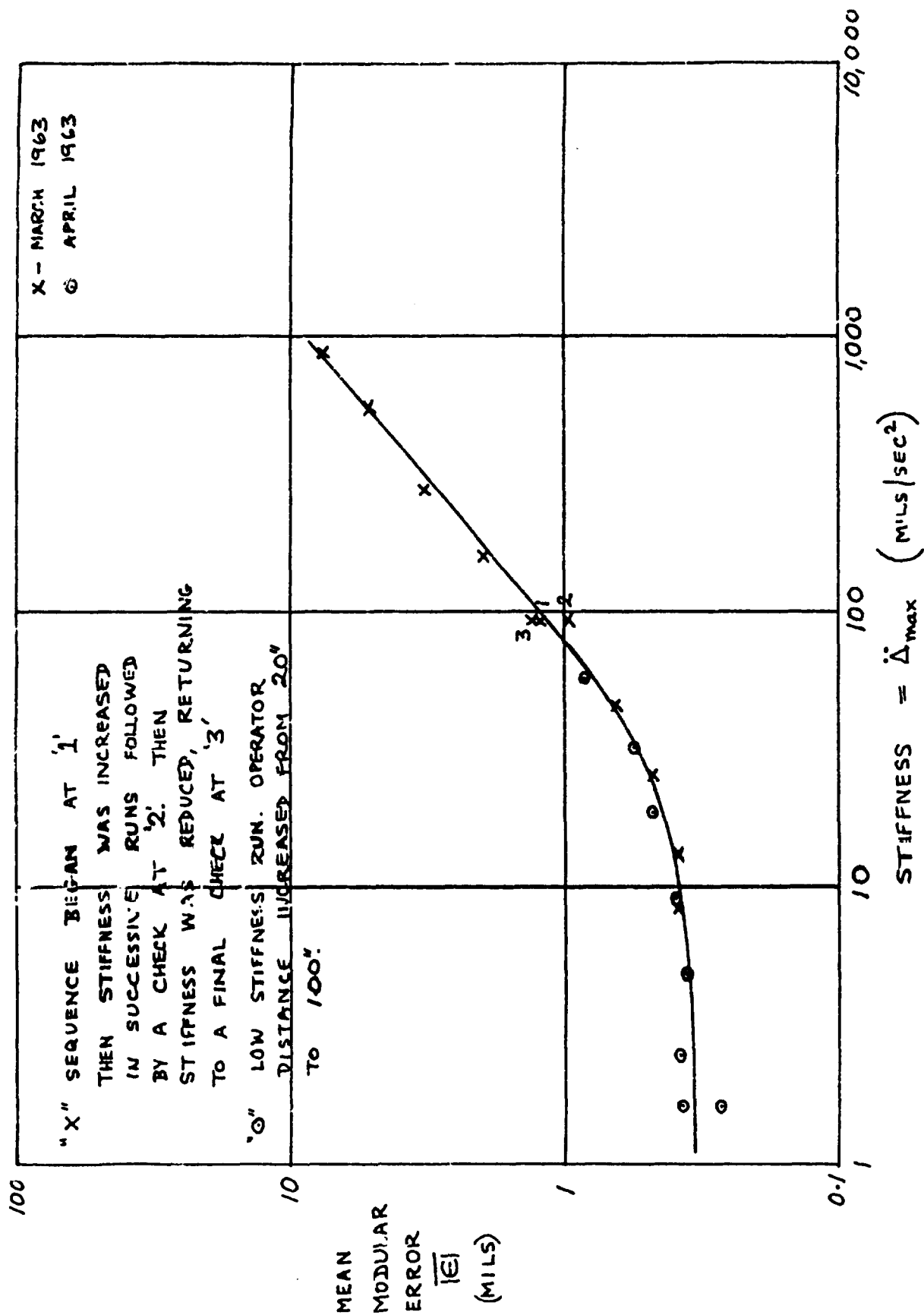
FIG. 2   STANDARD VARIATION OF MEAN MODULAR ERROR WITH STIFFNESS — NO LAG
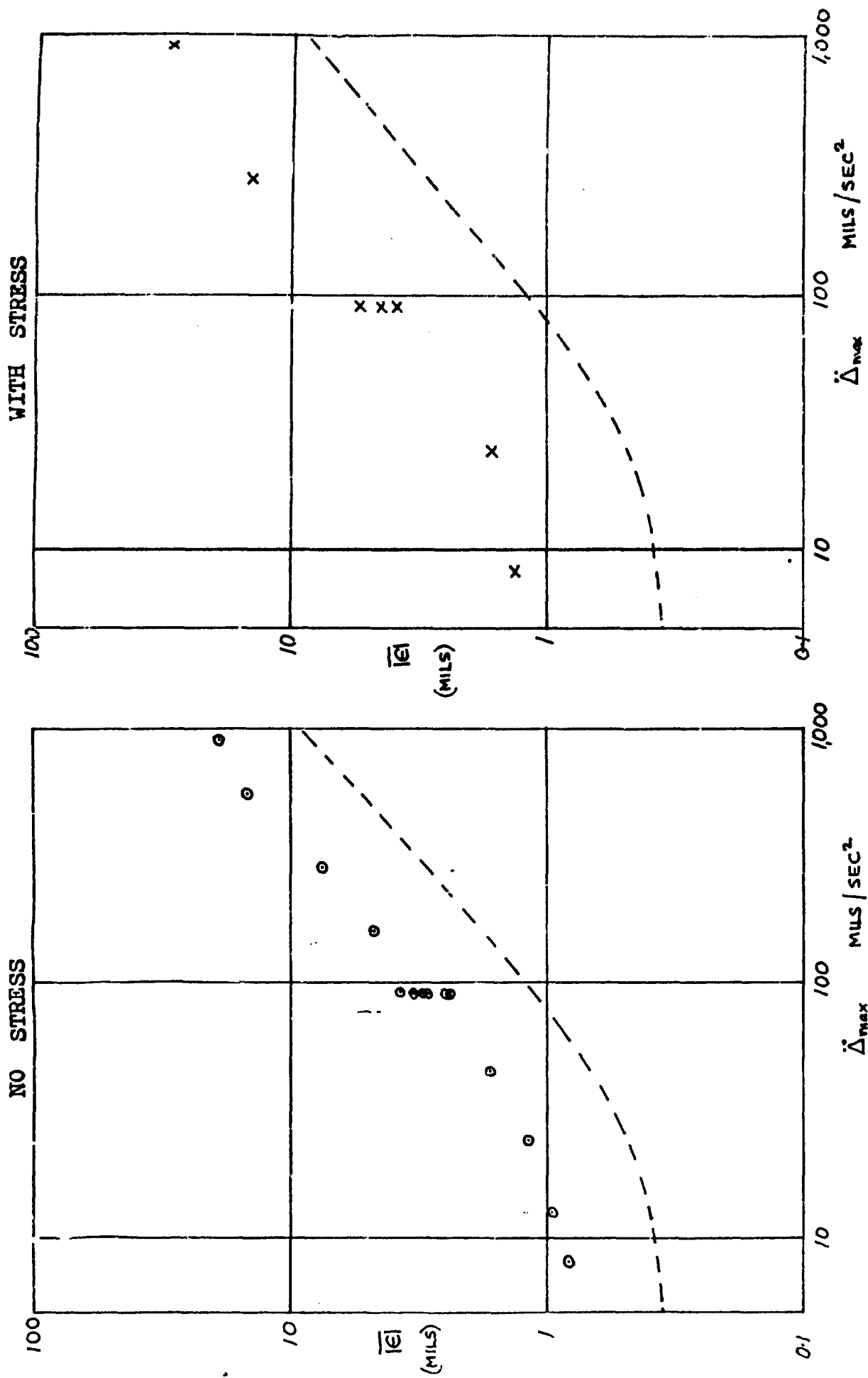
(SUBJECT = NORMAN K. WALKER)
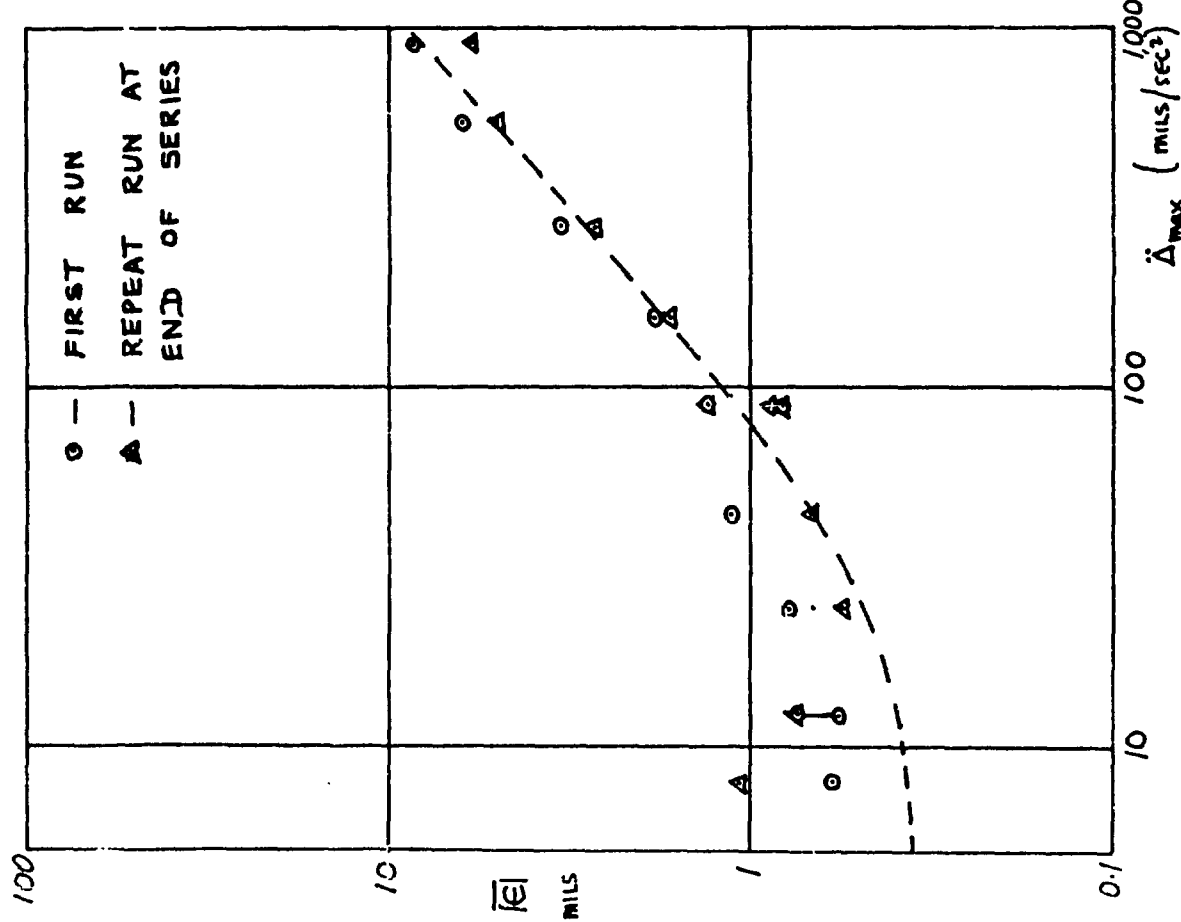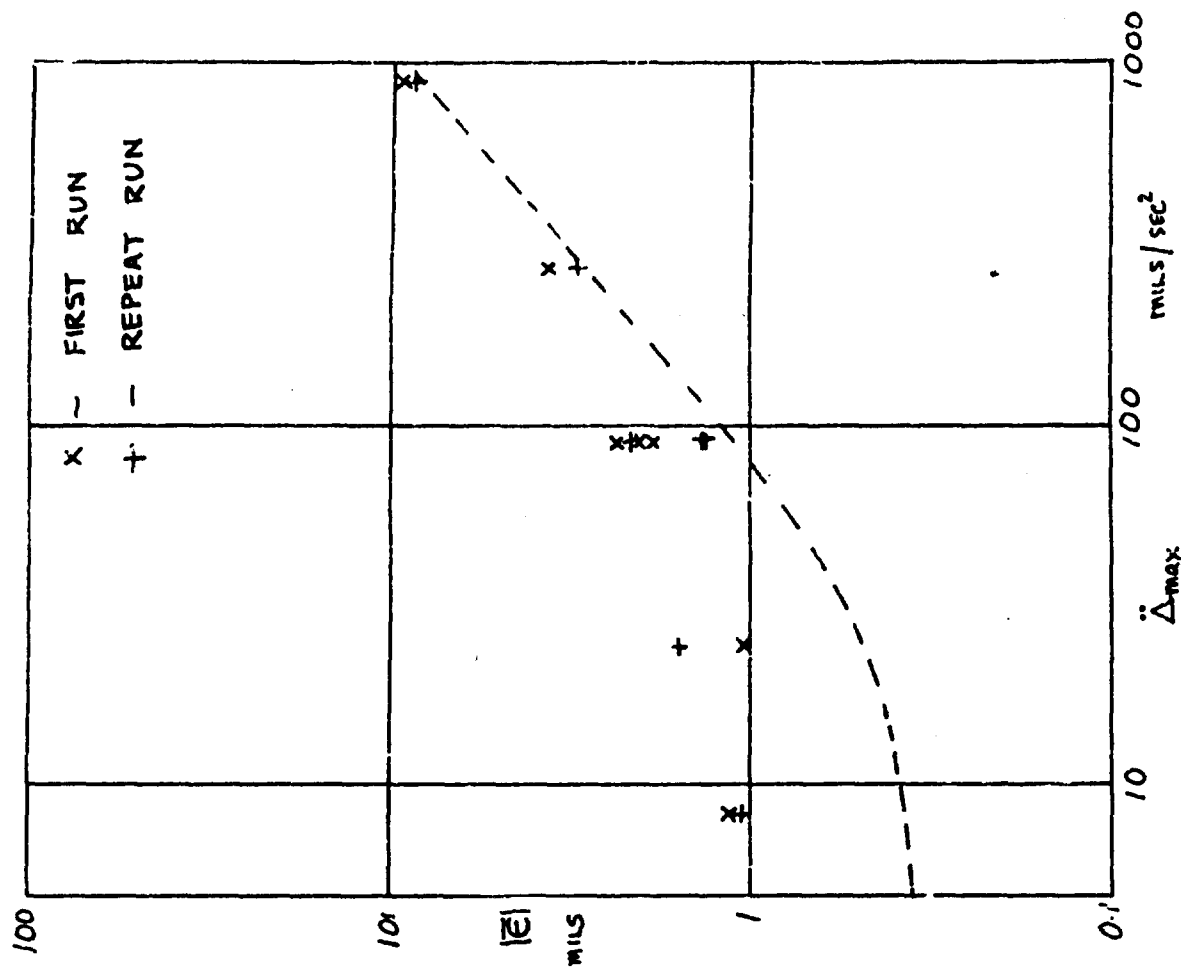
FIG. 3   EFFECT OF STRESS ON TRACKING ACCURACY - NO LAG

(SUBJECT - DR. HAMILTON MOWBRAY)

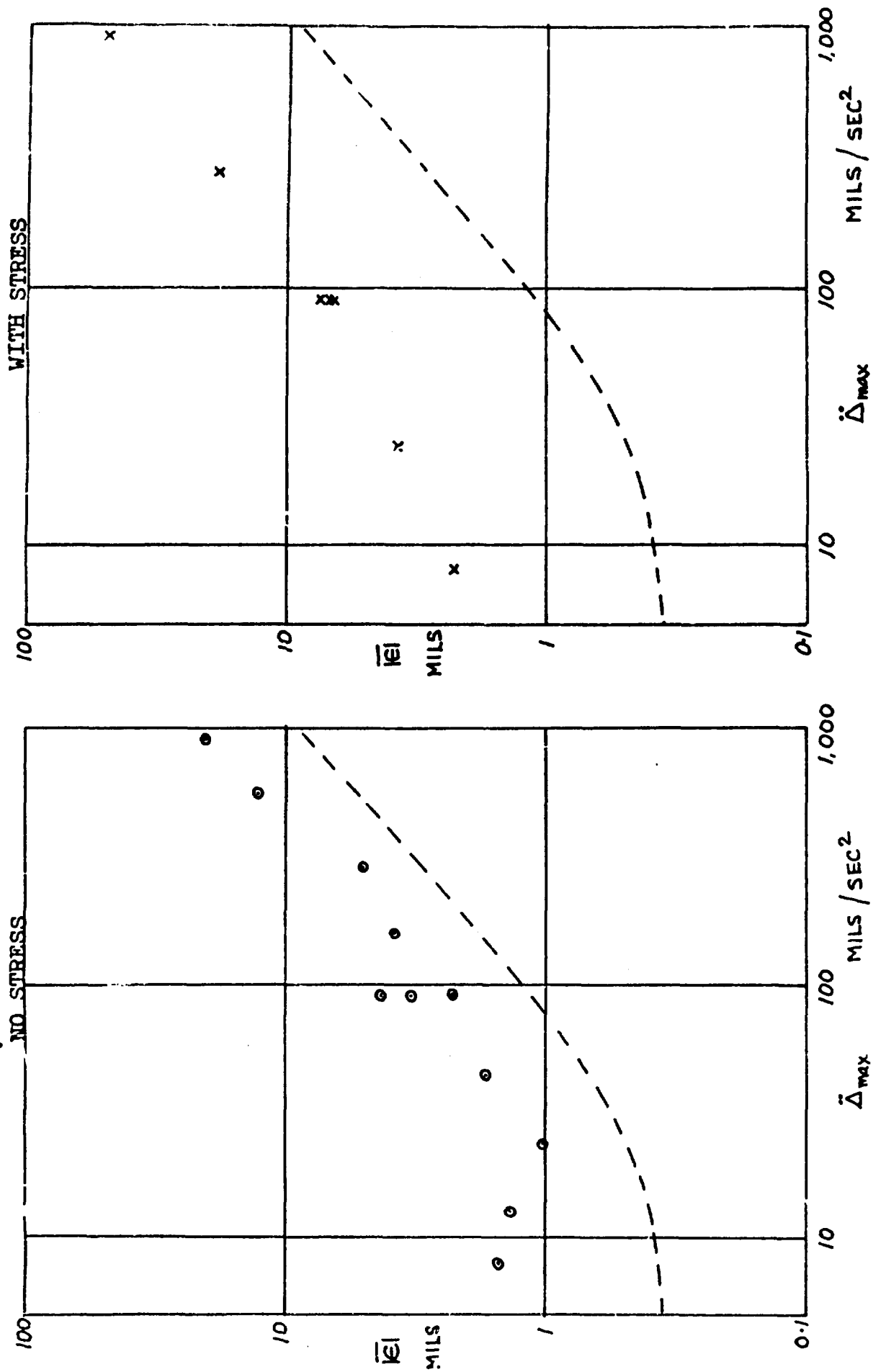FIG. 4   EFFECT OF STRESS ON TRACKING ACCURACY − 0.105 SECONDS LAG

(SUBJECT− DR. HAMILTON MOWBRAY)

FIG. 5   THE EFFECT OF STRESS ON TRACKING ACCURACY - .. 0.345 SECONDS LAG
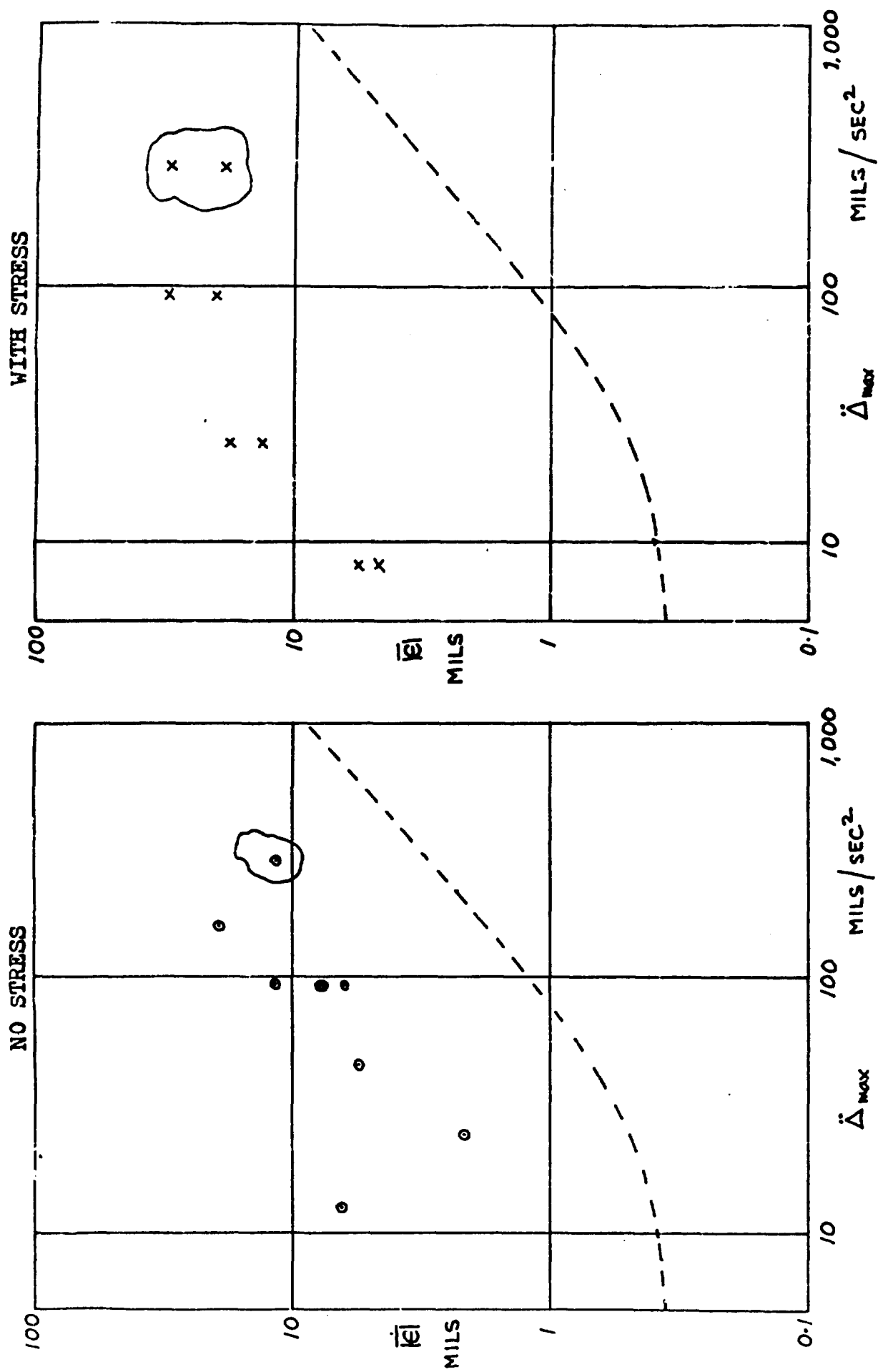
(SUBJECT - DR. HAMILTON MCWBRAY)

FIG. 6   EFFECT OF STRESS TRACKING ACCURACY - 1.255 SECONDS LAG

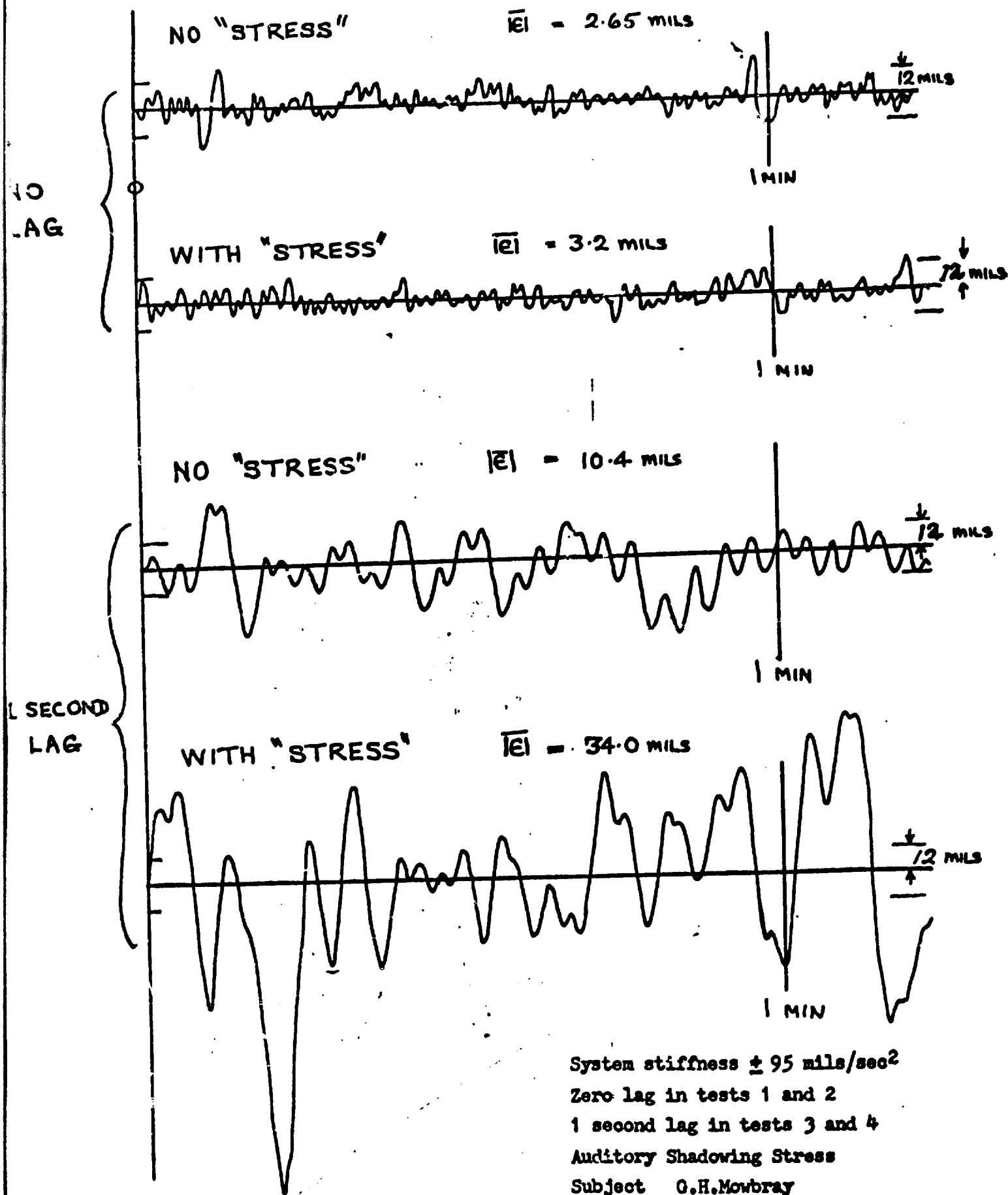(SUBJECT - DR. HAMILTON MOWBRAY)
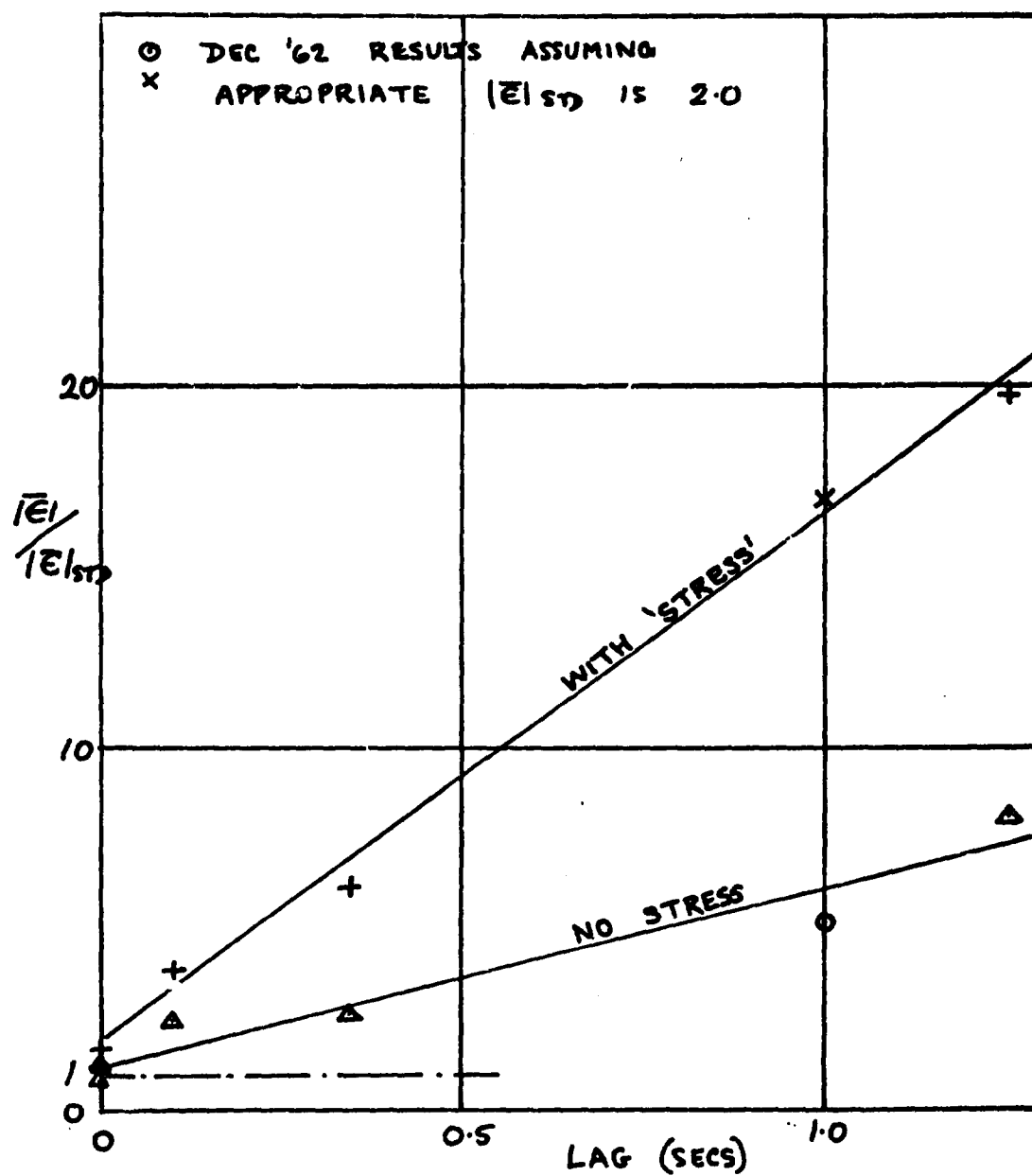
FIG. 7   EFFECT OF 'STRESS' ON 'RUBRIC' TRACKING

FIG. 8   EFFECT OF LAG ON ERROR RATIO, WITH AND WITHOUT "STRESS"